

Virtual Reality in Education: A Comparative Social Media Data and Sentiment Analysis Study

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Abstract—It is essential to consider the public’s viewpoints when it comes to significant issues, such as the adoption and integration of technologies in education. This study aims at analyzing and comprehending the public’s perspectives, sentiments and attitudes towards the use of virtual reality in general and in educational settings. After setting the necessary data requirements, 10,457,344 related tweets from Twitter were identified and retrieved from January 2010 to December 2020. The data was then analyzed using text mining and sentiment analysis. Based on the results, the public positively perceived the use of virtual reality and mostly expressed emotions of anticipation, trust and joy when referring to its use in education. Finally, the role of virtual reality as an effective educational tool that can enhance students’ engagement, motivation and academic performance was highlighted.

Keywords—virtual reality, extended reality, education, educational technology, immersive learning, social media, technology-enhanced learning, data analysis, sentiment analysis, data mining

1 Introduction

Education is currently undergoing reformation to address the arisen challenges and to meet the new educational needs and requirements of modern students and society [1]. Technology-enhanced learning is becoming more popular as a means to enrich education [2]. Extended reality technologies, that is mixed reality, augmented reality and virtual reality, are gaining ground as an invaluable educational tool that offers immersive learning environments [3]. Through these environments, interactive learning experiences which foster students’ learning motivation and engagement can be created [4].

Virtual reality allows users to actively interact with virtual objects and directly experience immersive environments in real time. Particularly, virtual reality involves the creation of computer-generated virtual environments which aim at simulating a user’s physical presence in specific real or artificial environments which perceptually surround users [5]–[7]. Virtual reality is in line with educational pedagogies as those rooted in constructivist ideals since it promotes and facilitates collaboration,

communication, increased engagement and interaction [8]. There are several benefits that can be yielded when adopting and integrating virtual reality in education [9], [10].

Based on the concept of crowd wisdom, the aggregation of information and the collective knowledge of public groups can lead to more efficient outcomes than those that strictly come from a handful of experts' opinions [11]. Therefore, it is crucial to comprehend the public's viewpoints and perspectives regarding this novel technology and its adoption in educational settings.

Social media is ruled by hybrid media logic [12] and constitutes a fundamental part of modern life as it allows users to collaborate, communicate, share opinions, content and knowledge, create a network of personal connections and interact in a common information space [13]–[15]. Social media creates and promotes a sense of belonging and socialization [16] and as it has significantly influenced the way people share and co-create information and knowledge in both educational and industrial contexts [17], it has become a vital tool for information discovery and dissemination, debate as well as opinion and knowledge sharing [18]. Consequently, social media can be regarded as a means through which data mining based on publicly available content can be conducted to extract the wisdom of the crowd on specific matters.

Following, this paper presents the justification, aims and research questions that led to the creation of this study, goes over the methodology and data analysis process and showcases and analyzes the results. Finally, it summarizes and discusses the main findings and drawn conclusions, goes over the challenges and limitations and provides directions for future research.

2 Justification, aims and research questions

Although the impact and usefulness of virtual reality has already been studied upon, there are limited studies which compare traditional face-to-face learning with immersive virtual reality experiences. Additionally, there are still gaps in the literature concerning the public's perspectives and attitudes towards the use of virtual reality in education as studies focus on specific samples.

Consequently, this study aims at bridging this gap by conducting a social media data analysis regarding the general use of virtual reality and its use in educational contexts. Twitter was selected as the preferred social media platform since it is widely considered to be the main platform that users utilize to publicly share concisely and precisely their viewpoints on matters the moment they take place [19]–[21].

More specifically, the Twitter Application Programming Interface (API) was used to identify and retrieve raw data from Twitter (tweets) over a ten-year span (January 2010 to December 2020). The specific time period was selected to offer a more coherent and complete overview of the state and advancement of virtual reality in both general use cases and in education as well as to present data gathered before the COVID-19 pandemic as it greatly affected several domains. As a result, two data sets regarding i) the general use of virtual reality and ii) the use of virtual reality in educational settings were generated. The data was then processed, analyzed and visualized to create new knowledge and results to better comprehend the public's perspectives and the evolution

of this novel technology. For that reason, the following two research questions (RQ) were set:

- RQ1: What are the public's perspectives, sentiments and attitudes towards the use of virtual reality in general?
- RQ2: What are the public's perspectives, sentiments and attitudes towards the use of virtual reality in education?

3 Methodology

This study follows the methodology and analysis process presented in the study conducted by [3]. Particularly, the methodology involves setting up the appropriate data requirements, identifying and collecting only the related data, processing the retrieved data and after analyzing it, visualizing the results in a comprehensible manner.

It is crucial to retrieve, process and analyze data of high quality to provide accurate and precise results and conclusions. Therefore, specific rules and aims (e.g., time periods, sources, variables, etc.) were set throughout all the processes (e.g., data retrieval, processing, analysis, visualization, etc.) with the aim of ensuring data accuracy and validity. In reference to the data identification and collection process, after testing out several keywords and hashtags both separately and in combination, the keywords selected for this study were: virtual reality, #VR, virtualreality for the data set concerning the general use of virtual reality, whereas for the data set regarding the use of virtual reality in education, the keywords were: virtual reality, #VR, virtualreality, learn, teach, train, education, university, college, school, class, student and pupil. In total, 10,457,344 tweets were retrieved from January 2010 to December 2020. Out of these tweets, 10,157,427 were about the use of virtual reality in general while 299,917 were about the use of virtual reality in education. The first data set involved data which contained at least one of the above-mentioned keywords, whereas the second one involved tweets which contained a combination of them (e.g. 'virtual reality' AND 'education'). All the publicly available information was retrieved for each tweet. It goes without saying that users' private information could not be retrieved.

After having retrieved the related data, the data was processed, cleaned and stored. Particularly, stop-words, URLs, punctuations and single characters were omitted where necessary. The text was converted into lower-case and the abbreviated words were expanded. The data sets were stored in JavaScript Object Notation (JSON) and Comma-separated Values (CSV) files. Finally, the data was analyzed and visualized both throughout the period of 2010–2020 as a whole and on a yearly basis. Customized graphs were created for each case (e.g., frequency of words, hashtags and mentions, number of tweets in general and per given interval, etc.).

3.1 Sentiment analysis

In addition to the aforementioned analysis, sentiment analysis was also carried out in the form of emotion and polarity detection to identify and understand the public's

sentiment concerning virtual reality. Sentiment analysis uses Natural Language Processing (NLP), text analysis, computational linguistics and biometrics to interpret and classify affective states and emotions within contextual texts.

Binary text classification (polarity detection) was used to detect the public's general sentiments (e.g., positive, negative or neutral) concerning the main research questions. For that reason, the open-source library TextBlob was used to conduct lexicon-based sentiment analysis [22]. To further validate the results, the rule-based tool for social media text sentiment analysis Valence Aware Dictionary for Sentiment Reasoning (VADER) was also used [23].

To identify the public's sentiment in relation to the main research questions, the National Research Council Canada (NRC) Word-Emotion Association Lexicon (EmoLex) which associates words with the eight basic emotions and two sentiments [24]–[26] was used as a basis for the lexicon-based emotion detection sentiment analysis. More specifically, EmoLex follows Plutchik's wheel of emotions which consists of joy and sadness, acceptance and disgust, fear and anger, surprise and anticipation [27], [28] and was set as the basis of the emotion analysis.

4 Results and analysis

Aiming at answering the research questions set and comprehending the public's perspectives regarding the use of virtual reality, the above-mentioned methodology was followed and two data sets containing Twitter data were created. Specifically, the data set involving the use of virtual reality in general contained 10,157,427 tweets, while the data set regarding the use of virtual reality in education contained 299,917 tweets. In total, 10,457,344 tweets were retrieved and analyzed from January 2010 to December 2020.

The tweets of each data set were analyzed both on a yearly basis and as a whole. The results are presented in the form of figures, diagrams and tables. The analysis involved the most frequently used hashtags and words, the number of tweets per month and year as well as polarity and emotion detection sentiment analysis.

4.1 General use of virtual reality

According to the keywords used, 10,157,427 related tweets were collected. Based on the analysis, the public's perspectives regarding the use of virtual reality in general from January 2010 to December 2020 were:

- Word frequency analysis: The top-5 most commonly used words including keywords were: *vr*, *reality*, *virtual*, *ar* and *via*. Table 1 presents the top-20 most commonly used words including keywords.
- Hashtag frequency analysis: *#VR*, *#VirtualReality*, *#vr*, *#virtualreality* and *#AR* were the top-5 most commonly used hashtags. Table 2 depicts the top-20 most commonly used hashtags.
- Frequency of tweets over the period of 2010–2020: The frequency of the tweets over the period of January 2010 to December 2020 are displayed in Figure 1.

- Sentiment analysis – Polarity detection: Based on the polarity analysis, the majority of the tweets were neutral, followed by positive and negative tweets, when using TextBlob (Figure 2), while the majority of the tweets were neutral, followed by positive and negative tweets, when using VADER (Figure 3).
- Sentiment analysis – Emotion detection: According to the emotion analysis, the emotion frequency based on the most intense emotion of each tweet was: Neutral, Anticipation, Trust, Anger, Joy, Fear, Surprise, Disgust and Sadness. The related data is displayed in Figure 4.

Table 1. Frequency of the top-20 most commonly used words within the tweets including keywords in the years of 2010–2020

Word	Freq.	Word	Freq.	Word	Freq.	Word	Freq.
reality	6,891,651	new	642,332	tech	458,588	future	318,930
virtual	6,776,767	oculus	593,164	3d	413,478	ai	296,717
vr	5,792,465	headset	557,119	experience	404,629	gaming	292,711
ar	741,303	game	525,340	technology	370,107	google	274,487
via	686,991	video	458,588	augmented	370,834	world	250,911

Table 2. Frequency of the top-20 most commonly used hashtags within the tweets in the years of 2010–2020

Hashtag	Freq.	Hashtag	Freq.	Hashtag	Freq.	Hashtag	Freq.
#VR	3802049	#AI	244152	#gamedev	116208	#ar	86645
#VirtualReality	962281	#tech	201637	#3D	112055	#indiedev	79976
#vr	869986	#IoT	168825	#Oculus	105903	#MR	78569
#virtualreality	693700	#blurreal	140928	#technology	105146	#Tech	76105
#AR	615182	#AugmentedReality	131402	#gaming	99185	#BigData	68587

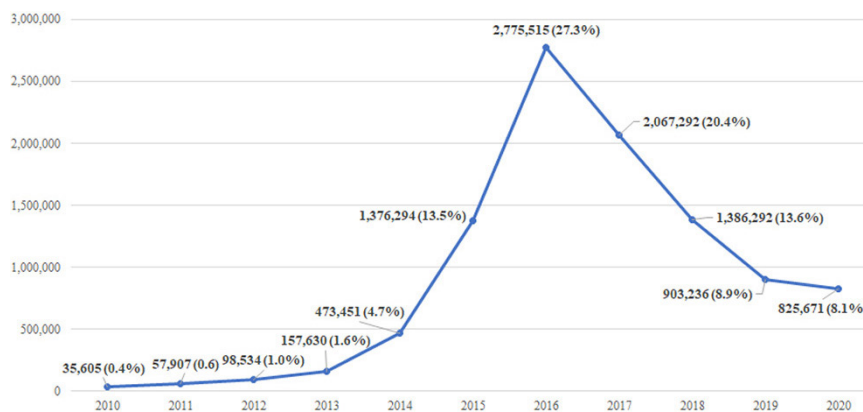


Fig. 1. Annual tweets over the years 2010–2020

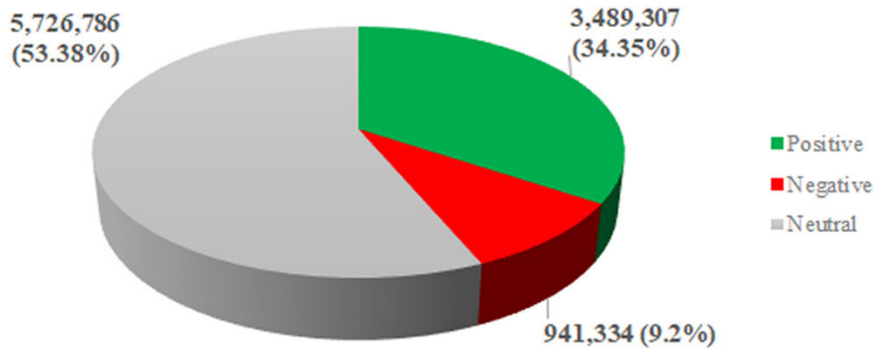


Fig. 2. Polarity frequency of the tweets over the years 2010–2020 using TextBlob

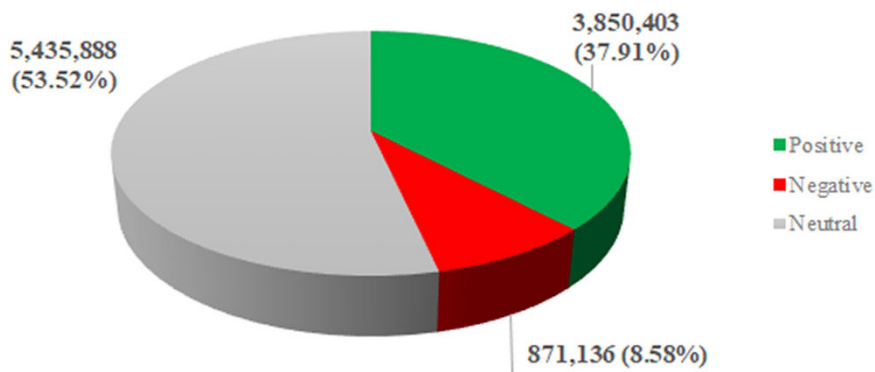


Fig. 3. Polarity frequency of the tweets over the years 2010–2020 using VADER

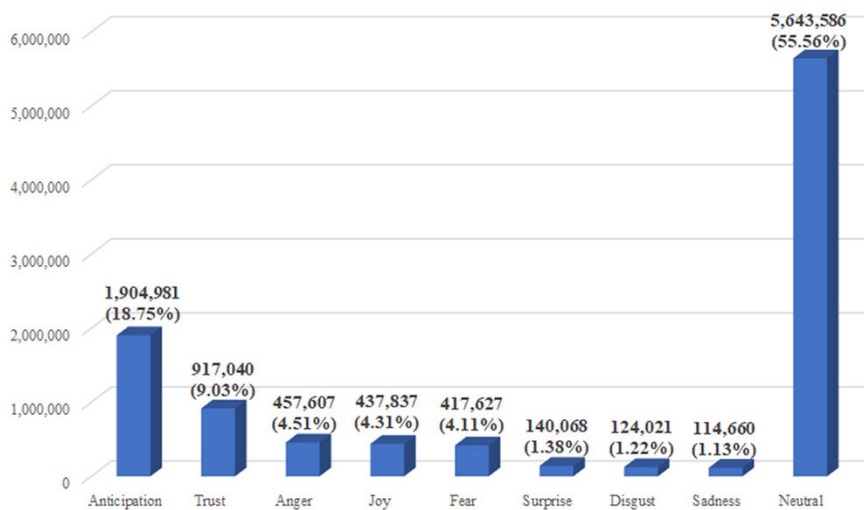


Fig. 4. Emotion frequency based on the most intense emotion of each tweet over the years 2010–2020

4.2 Virtual reality in education

Based on the keywords used, 299,917 tweets were retrieved. According to the analysis, the public’s perspectives regarding the use of virtual reality in education from January 2010 to December 2020 were:

- Word frequency analysis: The top-5 most commonly used words including keywords were: reality, virtual, vr, education and learn. The top-20 most commonly used words including keywords are presented in Table 3.
- Hashtag frequency analysis: #VR, #VirtualReality, #education, #AR and #edtech were the top-5 most commonly used hashtags. Table 4 presents the top-20 most commonly used hashtags.
- Frequency of tweets over the period of 2010–2020: The frequency of the tweets over the period of January 2010 to December 2020 are displayed in Figure 5.
- Sentiment analysis – Polarity detection: Based on the polarity analysis, when using TextBlob the majority of the tweets were neutral, followed by positive and negative tweets. When using VADER, the majority of the tweets were positive, followed by neutral and negative tweets. The related results are presented in Figures 6 and 7.
- Sentiment analysis – Emotion detection: According to the emotion analysis, the emotion frequency based on the most intense emotion of each tweet was: Neutral, Anticipation, Trust, Joy, Fear, Anger, Surprise, Sadness and Disgust. Figure 8 depicts the related data.

Table 3. Frequency of the top-20 most commonly used words within the tweets of the educational data set including keywords in the years of 2010–2020

Word	Freq.	Word	Freq.	Word	Freq.	Word	Freq.
reality	234,955	ar	35,500	train	26,086	university	18,081
virtual	226,367	edtech	33,823	technology	23,860	class	17,041
vr	172,733	student	33,097	new	23,748	experience	16,748
education	109,421	use	30,878	augmented	20,629	3d	16,021
learn	95,539	school	29,584	via	19,994	tech	15,747

Table 4. Frequency of the top-20 most commonly used hashtags within the tweets of the educational data set in the years of 2010–2020

Hashtag	Freq.	Hashtag	Freq.	Hashtag	Freq.	Hashtag	Freq.
#VR	121,439	#virtualreality	21,475	#3D	7,905	#edchat	6,188
#VirtualReality	44,094	#vr	17,884	#AugmentedReality	7,642	#learning	6,150
#education	35,220	#Education	11,961	#elearning	6,828	#technology	5,874
#AR	30,131	#AI	8,716	#tech	6,706	#art	5,367
#edtech	28,922	#ARVRinEDU	8,490	#history	6,511	#museum	4,899

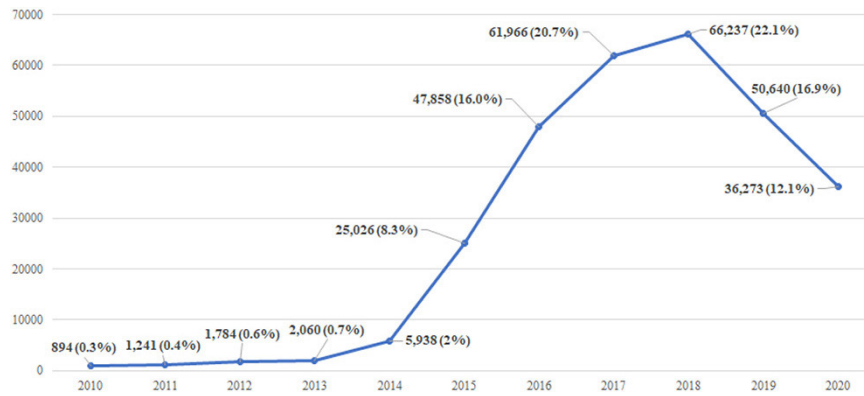


Fig. 5. Annual tweets over the years 2010–2020

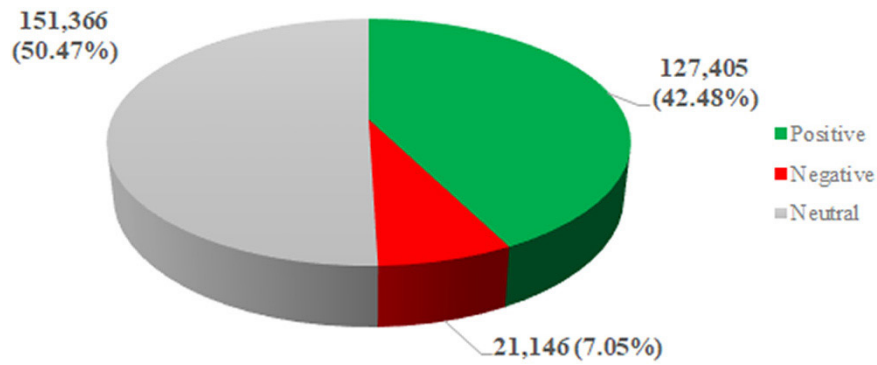


Fig. 6. Polarity frequency of the educational tweets over the years 2010–2020 using TextBlob

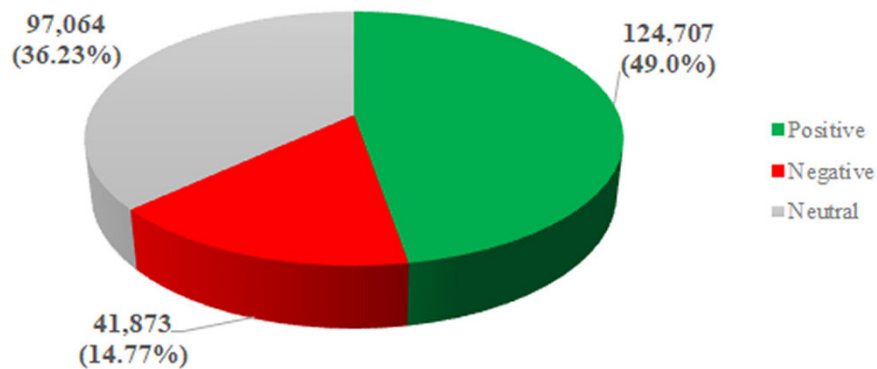


Fig. 7. Polarity frequency of the educational tweets over the years 2010–2020 using VADER

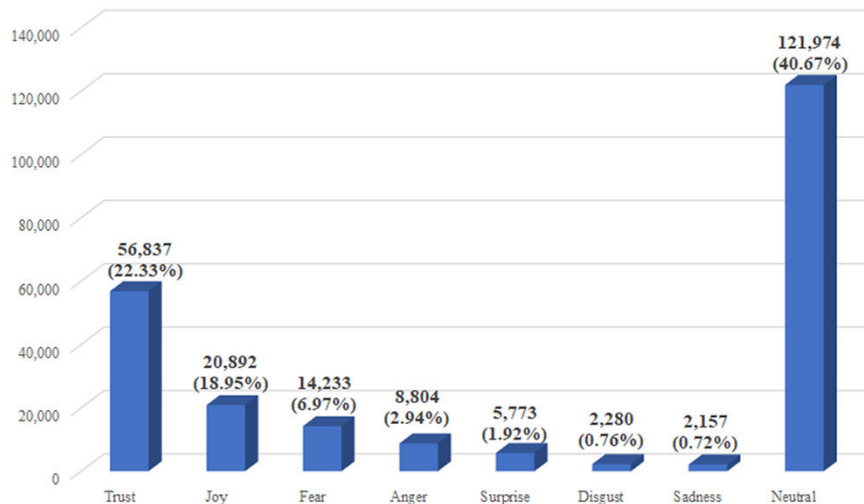


Fig. 8. Emotion frequency based on the most intense emotion of each tweet of the educational data set over the years 2010–2020

4.3 Analysis

Students’ engagement, motivation and active participation are vital contributors to academic success and the overall learning and teaching process [29]–[33]. Immersive technologies such as virtual reality can reinforce these aspects by offering students the ability to learn in safe and secure virtual environments which offer more vivid and interactive learning experiences [34], [35]. Adopting extended reality technologies in education in a student-centered manner can lead to increased and improved outcomes [36]. Additionally, it can effectively support and enhance the learning experience of students with special needs as well as their involvement and inclusion in educational activities [37]. To effectively integrate virtual reality into education, it is essential to take the viewpoints of both the educational community and the public into consideration. Social media can be used as an effective tool to amass diverse opinions and perspectives from people of different occupations, backgrounds, countries and ethnicity.

In this study, 10,457,344 related tweets were collected and analyzed to better comprehend the public’s perspectives regarding the use of virtual reality both in general and in educational contexts. The specific time period (January 2010 to December 2020) was selected as several advancements have been accomplished and the specific technology has been more accessible and more widely used. The results showcased that the majority of people were either neutral or positive concerning its general use and mostly expressed positive emotions, such as anticipation and trust. In the case of the use of virtual reality in education, the majority of the users were, once again, either neutral or positive and mostly expressed positive emotions, such as anticipation, trust and joy in reference to its adoption and implementation. As only a few tweets were negative, it can

be said that the majority of people found virtual reality a useful daily and educational tool. Moreover, in both cases, the results demonstrated the close relationship among extended reality technologies and a drastic increase in the number of tweets regarding this topic after 2016, which can be justified by the fact that 2016 is considered as a breakthrough year for virtual reality.

5 Limitations

Challenges faced during this study involved the definition of the most appropriate time period to retrieve the data, the selection of the most effective social media platform and Twitter API limitations. Moreover, some limitations were set (e.g., limiting the retrieval to tweets written in English) while others were inherent (e.g., privacy of personal data). Some data fields are set as private unless the specific user has made them publicly available. Despite the fact that some tweets contained this information (e.g., country), this information is not displayed in this study as even after being normalized, the data did not reflect the actual numbers.

Furthermore, as this study involved text analysis regarding virtual reality, some limitations are related to the sentiment analysis and specifically, to the fact that in some cases the concluded emotion and sentiment can be related to a particular experience and not to the technology itself. In spite of this limitation being a common phenomenon in similar studies, effort was put into minimizing its impact by manually filtering the retrieved tweets to include only those which are directly related to the use of virtual reality as a technology in education for the second data set.

6 Conclusions

As technology and technological applications are being rapidly integrated into the educational sector, more emphasis should be put on how their adoption and use is perceived by both the educational community and the public. Virtual reality is a contemporary technology which creates immersive and secure learning environments in which students are able to experiment and interact with digital objects and virtual content that otherwise would be impossible.

This study aimed at comprehending the public's perspectives, sentiments and attitudes towards the use of virtual reality in general and in education. After retrieving, collecting, processing and analyzing 10,157,427 related tweets, the results showcased that the public perceives virtual reality positively and mostly expresses emotions of anticipation, trust and joy when referring to it. Moreover, its close relationship with other extended reality technologies and its role as an effective educational tool that enhances motivation, engagement and academic performance were highlighted.

As there were many neutral tweets, it can be said that more effort should be put into promoting the effectiveness of virtual reality in education in order to integrate it into existing curricula and to secure resources to acquire the necessary equipment and develop virtual reality applications as it can constitute an efficient educational means which can be applied in all educational levels. Finally, future studies should

emphasize how the COVID-19 has affected the adoption of virtual reality in education and explore the crucial role of teachers and students in developing personalized virtual reality experiences.

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